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TESTING FOR THERMAL FATIGUE FAILURES IN SOLAR ARRAYS

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ABSTRACT

A temperature cycling test facility has been designed and constructed for the study of thermal stress and fatigue in solar arrays. Two bell jar type thermal vacuum chambers and their associated equipment and instrumentation provide close simulation of the space environment, automatic temperature cycling and data acquisition, and economical operation.

INTRODUCTION

The most severe environmental effect on a satellite solar array in long-term orbit is the thermal fatigue due to temperature cycling during the alternate sun/shade cycles. The severity also is increasing with the greater use of geosynchronous orbits where the temperature excursions are greater, and with the demands for longer orbit life and lower weight. Life testing of new solar panel designs for thermal fatigue thus has become a requirement for obtaining reliable power system performance when solar arrays are employed.

In order that testing for thermal stress and fatigue failures be meaningful, there must be close simulation of the space thermal environment, including:

(1) high vacuum and a "cold space" shroud
(2) the solar radiation intensity, uniformity and direction
(3) the time periods associated with test module temperature transients

Lockheed Missiles and Space Company has built two thermal vacuum chambers specially designed for the temperature cycling of large numbers of multi-cell solar panel modules in an accurately simulated space environment and at low cost.

FACILITY DESCRIPTION

The facility presently includes two thermal vacuum chambers. These are stainless steel, bell jar type chambers having a test volume 24 inches in diameter by 42 inches high. Two 9-inch diameter quartz windows on one side of the bell jar permit irradiation of the solar array modules by a Spectrolab X-25 solar simulator

to test electrical output of the modules. Eight tungsten filament lamps are installed inside each chamber to provide uniform radiant energy for the temperature cycling during normal life testing. A liquid nitrogen cooled shroud completely surrounds the test volume and includes movable shutters for the quartz windows. At the center of the chamber there is a box, or "target", 7.5 inches square by 21 inches high on which test modules are mounted. The box rotates so that different sets of modules can be positioned in front of the windows, and it is cooled with liquid nitrogen to provide the "cold space" environment on the back side of the test specimens.

The vacuum system consists of a 400 liter per second differential ion pump on each chamber. Initial roughing is accomplished with a carbon vane mechanical pump and a two-stage sorption pump. The roughing equipment is contained in a portable cart which is connected as needed to either vacuum chamber.

A standard solar array module size was established with dimensions of approximately 3.5 inches by 5 inches. Thus a module might be, for example, an assembly of 12 2cm. by 4cm. solar cells. However, any module having a diagonal dimension of 9 inches or less can be tested when the solar simulator is to be used. Larger test articles also can be tested, and the rotatable box can be removed to permit testing of one or two panels up to 2 ft. by 3 ft.

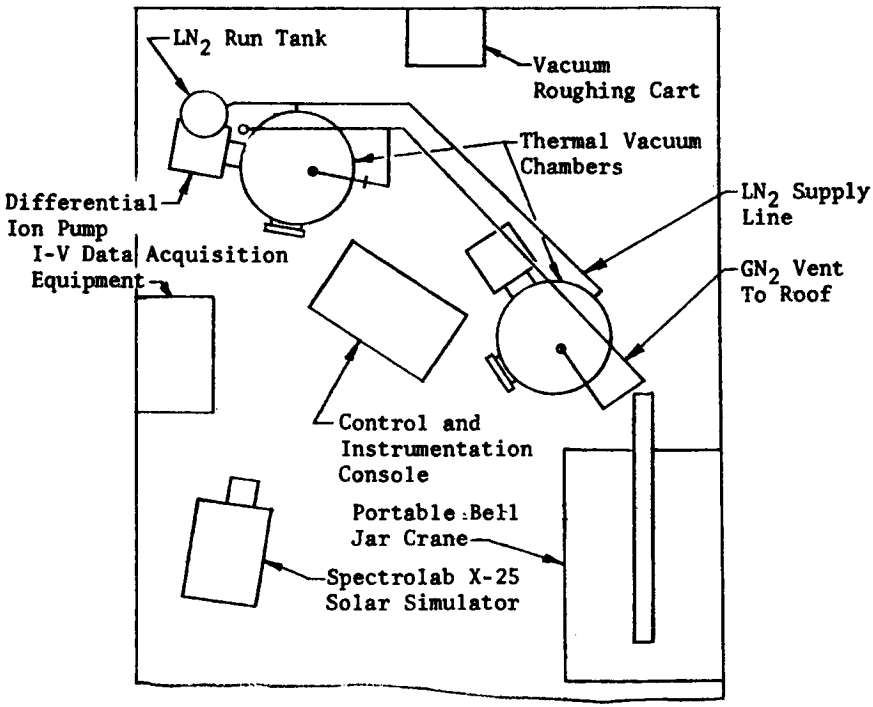

Fig. 1 - Thermal Cycling Facility Layout

FACILITY PERFORMANCE

The ion pumping, together with some cryopumping by the liquid nitrogen shroud system, yields a vacuum level below 10^{-7} torr when the chamber is clean and empty. Outgassing by the test articles will raise this pressure; however, the ion pump can maintain a chamber pressure of 6×10^{-5} torr with an air in-bleed of 8 micron liters per second and without liquid nitrogen in the shroud.

The chambers are designed to operate in the temperature range from -191°C to 300°C, and there is potential for lowering the minimum temperature several degrees. The interior tungsten filament lamps can direct from 0 to 4 solar constants of uniform radiant energy onto the test modules. Temperature cycles can be obtained by programming either the radiant energy intensity or module temperature vs. time. Two 40-channel digital recorders give both test module temperature and electrical output data. Complete, automatic data acquisition equipment is provided for round-the-clock, unattended facility operation.

A summary of test results to date will be presented.

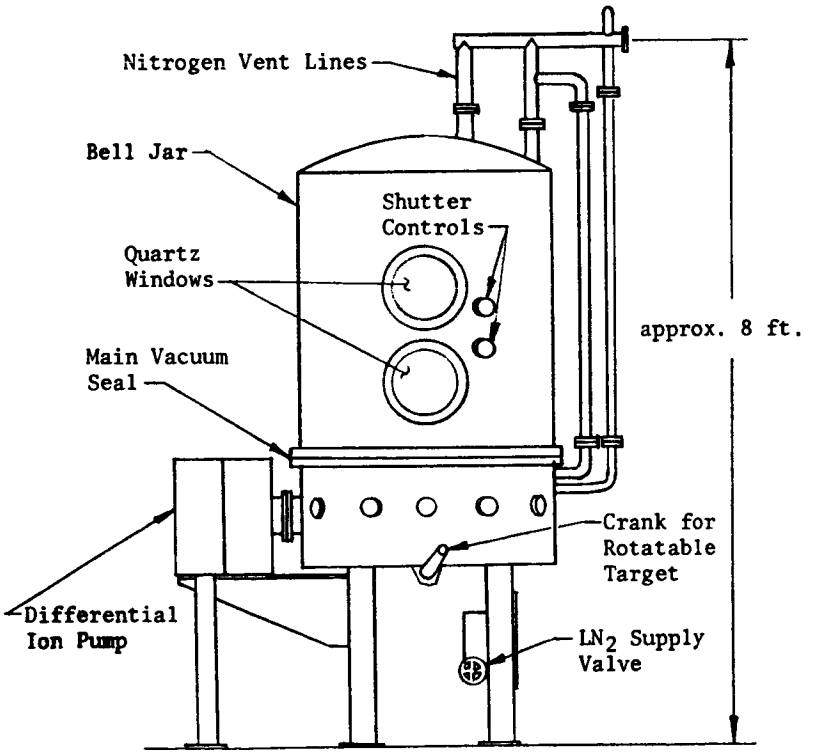

Fig. 2 - Thermal Vacuum Test Chamber